THE INHIBITION OF ALUMINIUM CORROSION IN HYDROCHLORIC ACID SOLUTION BY HYDROXYETHYLCELLULOSE

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ABSTRACT

Corrosion inhibition of aluminium AA1060 in 1.0M HCl and 1.5M HCl by HEC was investigated using weight loss method under atmospheric exposure. The results revealed that HEC inhibited the rate of corrosion attack on the metal in HCl medium. Corrosion rates increased with increase in acid concentration. The inhibition efficiencies increased from 27.744% for the lowest inhibitor concentration to 57.317% for the highest concentration of the inhibitor for aluminium corrosion in 1.0MHCl. Similarly, the inhibitor (HEC) showed efficiencies in the range from 35.893% to a maximum of 58.157% for aluminium corrosion in 1.5M HCl. The corrosion current was also studied and it decreased with increase in inhibitor concentration.

***Keywords**: Aluminium; Hydroxyethylcellulose; corrosion inhibition; corrosion current; Inhibition Efficiency.*

INTRODUCTION

Aluminium is employed widely in most industries due relatively to its low cost and availability for the fabrication and construction industries. However, during service these metals come in contact with aggressive environments which negatively affect their stability in service, a phenomenon called corrosion. Hence, corrosion may be defined as the deterioration of a metal or its properties due to its reaction with its environment (Umoren, 2008). The increasing number of structures suffering corrosion makes the study of their structural safety of importance. To reduce the corrosion problem in these environments, inhibitive effects of various chemical compounds and naturally occurring substances have been evaluated as effective corrosion inhibitors (Sanghavi et al., 1995). These chemical compounds may include phosphates, chromates, dichromates, silicates, borates, tungstates, molybdates and arsenates and have also found useful application in the formulation of primers and anti-corrosive coatings, but a major disadvantage is their toxicity and as such their use has come under severe criticism (Oguzie et al., 2004; and Quraishi and Sharma, 2005). Hence the use of polymers and their compounds which are non-toxic are employed. Polymers combine good chemical resistance with impermeability to different media and unusual deformation characteristics. The use of polymers as corrosion inhibitors has been reported (Shinde et al (2005) ; Pawar et al (2007); Torresi et al (2005); Souza de (2007) and Vera et al (2007).

The inhibitive characteristics of such components derive from the adsorption ability of their molecules with the polar group acting as the reaction centre for the adsorption process. The resulting adsorbed film acts as a barrier that separates the metal from the corrodent and efficiency of inhibition depends on the mechanical, structural and chemical characteristics of the adsorption layers formed under particular conditions (Martinez and Stern, 2002; Oguzie, 2004; Oguzie , 2008). The inhibition of aluminiu corrosion in hydrochloric acid solution by exudates gum from Raphia hookeri has also been studied (Umoren, et al., 2008).

Experimental Technique

Aluminium sheet of the type AA1060 and purity of 98% and composition. (wt. %) S_i = 0.12, Fe = 0.02, Mn = 0.04, and the remainder AL, was obtained from System Metal industries limited Calabar, Nigeria. The Aluminium sheets of thickness, 0.05cm were mechanically press cut into 4cm x 2cm coupons. A small hole was drilled at one side of the coupons to support the hook. The coupons were polished mechanically using silicon carbide papers of grade no. 166, washed thoroughly with distilled water and degreased with ethanol and acetone and air dried. Stock solutions of 0.0005M, 0.0010M, 0.0015M, 0.0020M and 0.0025M of HEC (Hydroxyethylcellulose) were prepared. Similarly, Stock solutions of 1.0M HCl and 1.5M HCl were prepared using serial dilution principle.

Gravimetric (Weight loss) measurements

250ml beakers containing different concentrations of HCl solution and HEC solution were used. The weighed aluminium coupons were suspended in the beaker with the aid of glass rods and hooks. The coupons were retrieved at 24-hour interval, progressively for 7 days (168hours); washed by immersion in distilled water and ethanol. At the end of the test, the coupons were carefully washed in absolute ethanol and nitric acid to quench further corrosion. The weight losses of coupons were evaluated in grammes as the difference between the initial weight before immersion and weight after immersion. From the results obtained the following corrosion parameters were evaluated:

Corrosion Rate: This is expressed in millimeter per year (mm/yr) (Vipin et al. 2009)

$$\text{Corrosion rate (mm/yr)} = \frac{87600W}{\rho A t}$$

Where W = weight loss in grammes (g)

ρ = density of the coupon (g/cm^3)

A = area of coupon in cm^2

t = time of exposure (hours)

Inhibition Efficiency (IE%): This is percentage by which corrosion rate is reached in the presence of inhibitor compared with the rate in which corrosion occurs without inhibitor ie

$$IE\% = [1- (W_1/W_0)] \times 100$$

Where W_1 = weight loss in the presence of inhibitor

W_o = weight loss in the absence of inhibitor

Surface coverage (θ):- This is the area covered by the inhibitor.

$$\theta = [1- (W_1/W_0)]$$

RESULTS AND DISCUSSIONS

The weight loss of the aluminium in 1.0M HCl and 1.5M HCl with and without different concentrations of HEC was determined after 24-hour interval progressively for 7 days (168 hours) under atmospheric exposure. The corrosion rates, inhibition efficiencies and surface coverage values were evaluated and presented in Tables 1.0 and 2.0.

Corrosion rates increased with increase in acid concentration. It was also observed that corrosion rates decreased with increase in concentration of the inhibitor (HEC). This showed that HEC in solution inhibited the corrosion of aluminium in HCl. The inhibition efficiencies increased from 27.744% for the lowest inhibitor concentration to 57.317% for the highest concentration of the inhibitor for aluminium corrosion in 1.0MHCl. Similarly, the inhibitor (HEC) showed efficiencies in the range from 35.893% to a maximum of 58.157% for aluminium corrosion in 1.5M HCl.

Table 1.0

Calculated values of corrosion rate (mm/yr), inhibition efficiency (IE %) and degree of surface coverage (θ) for Hydroxyethylcellulose (HEC) in 1.0M HCl corrosion of Aluminium from weight loss data.

Inhibitor Concentration	Corrosion Rate (mm/yr)	Inhibitor Efficiency (I.E. %)	Degree of Surface Coverage (θ)
Blank	4.059	-	-
$5.0x10^{-4}M$	3.056	27.744	0.277
$1.0x10^{-3}M$	2.704	42.988	0.430
$1.5x10^{-3}M$	2.148	44.817	0.448
$2.0x10^{-3}M$	2.059	52.134	0.521
$2.5x10^{-3}M$	1.996	57.317	0.573

Table 2.0

Calculated values of corrosion rate (mm/yr), inhibition efficiency (IE %) and degree of surface coverage (θ) for hydroxyethylcellulose (HEC) in 1.5M HCl corrosion of Aluminium from weight loss data.

Inhibitor Concentration	Corrosion Rate (mm/yr)	Inhibitor Efficiency (I.E. %)	Degree of Surface Coverage (θ)
Blank	7.047	-	-
$5.0x10^{-4}M$	4.644	35.893	0.359
$1.0x10^{-3}M$	3.939	45.489	0.455
$1.5x10^{-3}M$	3.678	48.560	0.486
$2.0x10^{-3}M$	3.244	52.207	0.522
$2.5x10^{-3}M$	2.783	58.157	0.582

Figures 1 and 2 show the plots of weight loss against time for aluminium corrosion in 1.0M HCl and 1.5M HCl respectively with and without different concentrations of HEC studied under atmospheric exposure. The Figures clearly depicted a reduction in weight loss of the aluminium coupons from when the metal was in HCl without HEC to when it was in the acid in the presence of HEC up to maximum concentration used. Further inspection of the Figures (1 and 2) revealed that the loss in weight of the Al coupons decreased with increasing concentration of the inhibitor.

However, greater weight loss was observed for Al corrosion in 1.5M HCl than in 1.0M HCl.

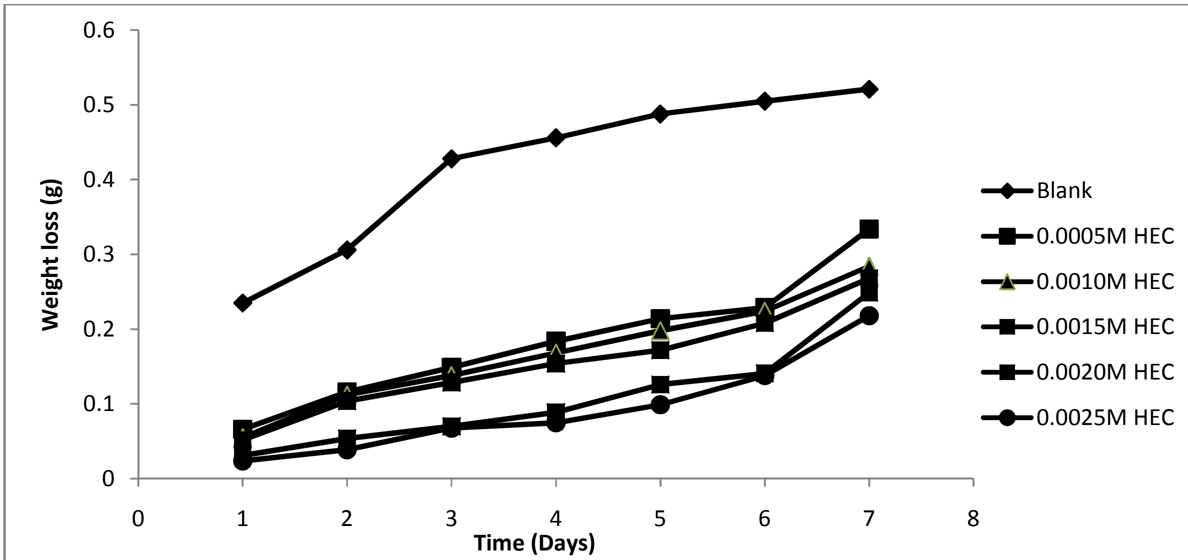

Fig. 1: Weight loss against Time for Aluminium corrosion in 1.5M HCl with and without different concentration of HEC.

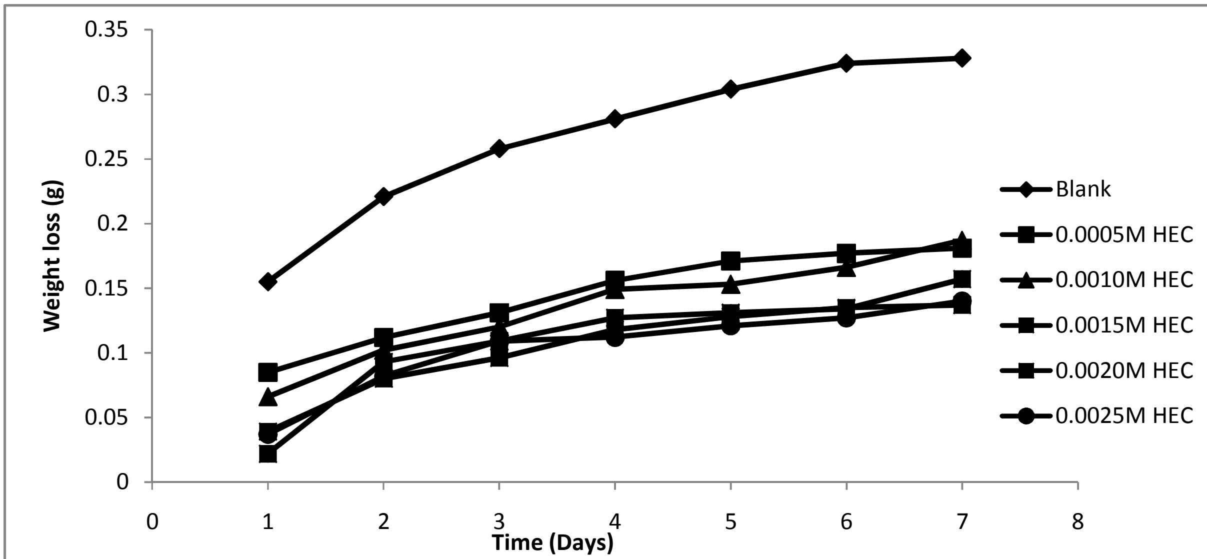

Fig.2: Weight loss against Time for Aluminium corrosion in 1.0M HCl with and without different concentration of of HEC

The trend of corrosion rates, inhibitor efficiencies and surface coverage are shown in Figures 3, 4 and 5 respectively. The corrosion rate decreased with increase in inhibitor concentration. It was also observed that corrosion rate was higher in 1.5M HCl than in 1.0M HCl. As shown, inhibition efficiency and surface coverage increased with inhibitor concentration.

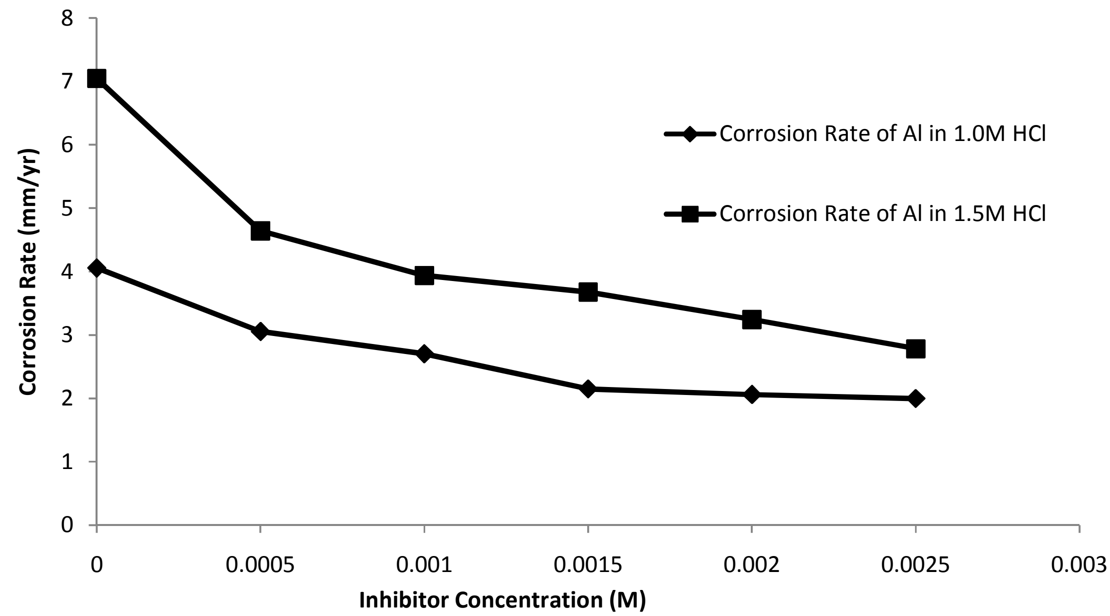

Fig. 3: Corrosion Rate of Aluminium with and without HEC in 1.0M HCl and 1.5M HCl

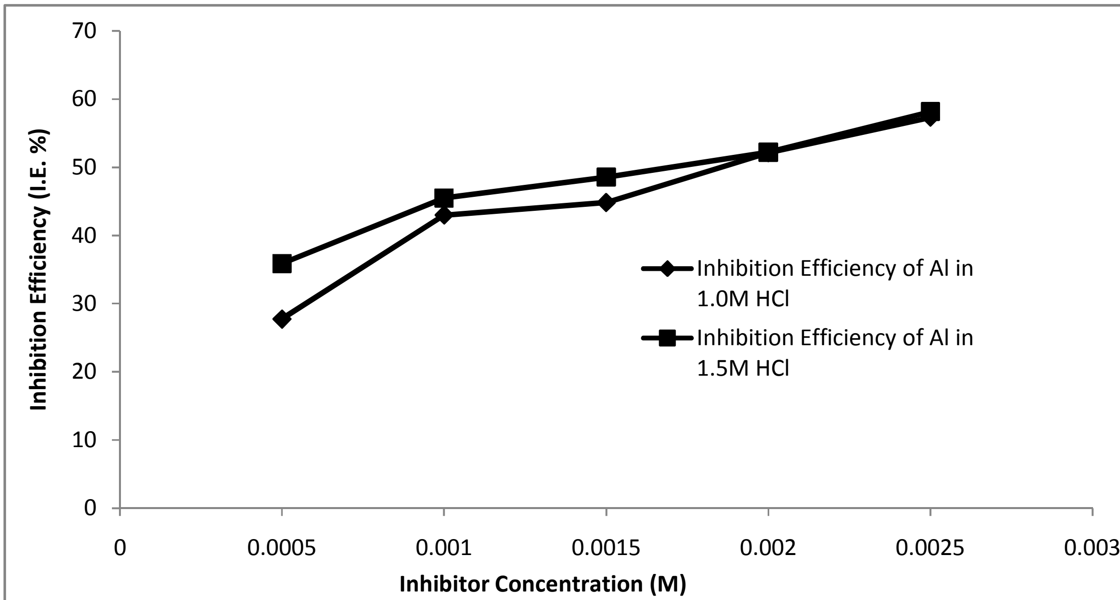

Fig. 4: Inhibition Efficiency of Aluminium Corrosion in 1.0M HCl and 1.5M HCl with HEC

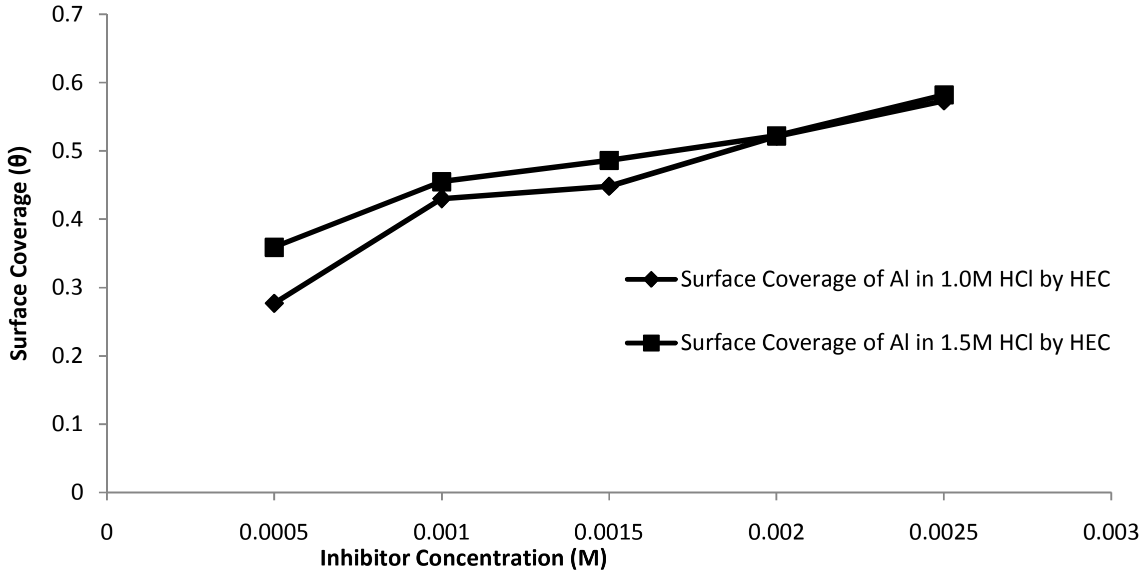

Fig. 5: Degree of Surface Coverage of Aluminium in 1.0M HCl and 1.5M HCl by HEC

Corrosion Current

Corrosion current is determined from the expression (Jonnes, 1996):

$$I_{corr} = \frac{CR \times \rho \times A}{K \times Ew}$$

Where I_{corr} = corrosion current in Amps.

CR = corrosion rate in mm/yr

ρ = density of metal coupon in g/cm^3

A = Area of coupon in cm^2

K = Constant that defines the units for the corrosion rate

Ew = Equivalent weight of corrodent in grams/equivalent

The corrosion current values for aluminium corrosion in HCl has been presented in Table 3. From the graphical illustration in Figure 6, the corrosion current reduced asymptotically with increasing concentration of hydroxyethylcellulose.

Table 3. Calculated values of corrosion current (Amps) for Aluminium corrosion in 1.0M HCl and 1.5M HCl.

Inhibitor Concentration	1.0M HCl	1.5M HCl
Blank	4.826 x 10^{-5}	7.665 1x 10^{-5}
0.0005M	3.487 x 10^{-5}	4.912 x 10^{-5}
0.0010M	2.752 x 10^{-5}	4.177 x 10^{-5}
0.0015M	2.662 x 10^{-5}	3.943 x 10^{-5}
0.0020M	2.221 x 10^{-5}	3.663 x 10^{-5}

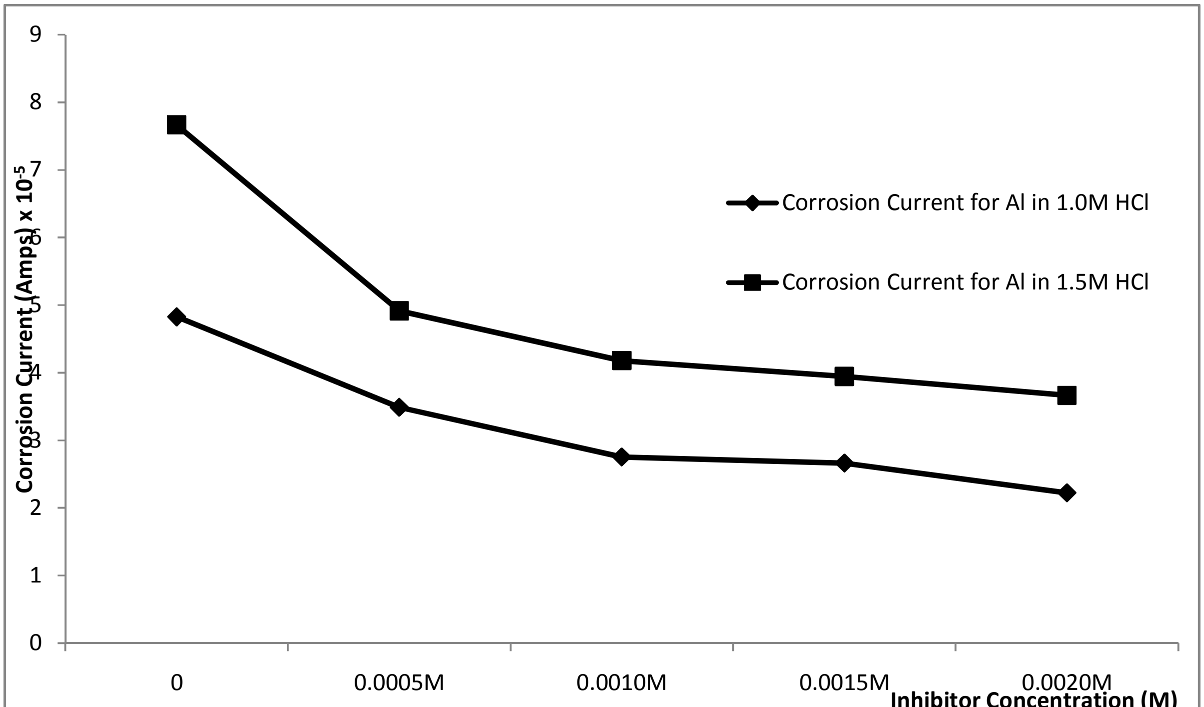

Fig.6 : Corrosion Current for AluminiumCorrosion in 1.0M HCl and 1.5M HCl

CONCLUSION

1. Hydroxyethylcellulose was found to be effective water-soluble, eco-friendly inhibitor for aluminium (AA1060) in 1.0M HCl and 1.5M HCl solutions.
2. Corrosion rate increased with increase in corrodent (HCl) concentration but decreased as inhibitor concentration increased.
3. The inhibition efficiency and surface coverage increased with increase in inhibitor concentration.
4. The corrosion current decreased with increase in inhibitor concentration.

ACKNOWLEDGEMENT

The authors are very grateful to Mr. Vincent N. Uchegbu for his technical assistance.

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